North Carolina Department of Transportation

Chapter 5 Drainage Plans Development

January 2022

Revisions Sheet			
Page	**Old Section**	**New Section**	**Description**
-	-	-	• Entire Chapter revised to new format and minor grammatical changes made throughout • All references and links have been updated throughout Chapter
1	-	5.1	Added new section – Introduction; Subsequent sections renumbered
2	5.1	5.2	Last paragraph – Removed reference to Appendix D, Item 4. Now references HPR
-	5.2	-	Section deleted
5	5.3	5.2.2	Section moved to be included under 1st bullet
5	5.3	5.2.2	Last Paragraph – Removed reference to Appendix E; revised links
4	5.5	5.2.2	12th bullet – Removed hazardous spill basins; replaced with Stormwater Control Measures (SCMs)
5	5.5	5.2.2	Last paragraph – Removed reference to Appendix B; revised links
6	6.1	5.3.1	Added 2nd bullet – Subsequent bullets renumbered
6	6.1	5.3.1	10th Bullet – Removed references to Appendix T; refers to Section 5.4
7	6.1	5.3.1	11th Bullet – Removed references to Appendix B; revised links
7	-	5.4	Added new section – Items to Include on Redline Drainage Plans
8	-	5.5	Added new section – Completing 3D Series Hydraulic Summary Plan Sheets (Including Drainage Summary Sheets and Stormwater Control Summary Sheets)
10	6.2	5.6	• Removed references to Appendices; revised links • Last sentence revised
12	-	5.7	Added new section – References
13	-	5.8	Added new section – Additional Documentation
13	Appendix B	5.8	Drainage Design Field Investigation Checklist link added

	Appendix D – Item 4	5.8	Replaced with the Hydraulic Planning Report Template (link)

Table of Contents: Chapter 5, Drainage Plans Developement

5.1 Introduction

The purpose of a drainage study is to determine how to best convey stormwater runoff associated with the roadway to a natural drainage outlet safely, efficiently, aesthetically, and with environmental stewardship. Field investigations, data collection, observation, and computations are part of the drainage study. A report is generated for the study, the format of which is dependent on the project. This chapter discusses drainage plan development for a typical roadway project.

5.2 Field Reconnaissance and Survey

The Location and Surveys Unit, in conjunction with the Photogrammetry Unit, provides the survey data required for the development of hydraulic design plans. The type and presentation format of these data are provided in the Location and Surveys Unit's document *NCDOT Field Surveys for Hydrographic Data* (NCDOT 2007 (rev. 2010)).

Typical survey data required for hydrologic and hydraulic studies include:

- existing bridge superstructure and substructure locations and elevations
- existing culvert dimensions, including invert elevations, top slab depth, multi-barrel web thickness, condition, etc.
- pipe sizes and condition, invert elevations
- existing drainage channels, including size, slope, stability, etc.
- condition of drainage structure and invert elevations
- storm drain system components
- curb and gutter locations
- streams and ponds (location, geometry, hydraulic characteristics, stability, outlet structure etc.)
- topographic features (e.g., paved areas, buildings, wooded areas, etc.)
- digital terrain model (DTM) and LiDAR

Wetlands and jurisdictional streams are delineated by the Environmental Analysis Unit (EAU) and verified by the US Army Corps of Engineers (USACE) and/or the NC Department of Environmental Quality (NCDEQ) staff. Survey data for transportation improvement projects are compiled and stored in a single final survey MicroStation file.

For specialty or unusual survey needs, such as bathymetric surveys in sounds, large rivers, ponds or lakes, the Location Engineer may need to coordinate with the design engineer to define the survey coverage area and data requirements during the initial stage of the survey.

It is the primary Design Engineer's responsibility to verify and supplement the survey data in the field prior to commencing detailed design to ensure that these survey data are accurate for use in developing the hydraulic model analyses, bridge and culvert survey and hydraulic design reports and drainage plans. The Design Engineer should

consider the level of data needed for the hydrologic and hydraulic analyses to be performed. This should be compared with the survey data provided by the Location and Surveys and Photogrammetry Units to determine what additional data must be obtained, such as stream bed slope, and channel geometry (at locations where detailed stream cross sections may be needed). If the accuracy of the survey data is in question or if additional field surveys are warranted, request assistance from the Location and Surveys Unit staff. The Hydraulic Planning Report (HPR) includes a list of field information to be collected in the preliminary design phase of the project, which may later be supplemented with more detailed survey information in the final design stage.

5.2.1 Drainage Field Reconnaissance

When conducting a field survey for a roadway drainage structure such as a bridge or culvert, the highway drainage structure must be designed to satisfy the following constraints for the duration of its structural life:

- safely conveys the design flow to prevent inundation of the travel way without creating excessive flooding on upstream or downstream properties
- does not create flow velocities causing excessive scour erosion in the outlet channel or on the roadway fill at the inlet
- structurally supports the roadway and traffic loading
- provides adequate means for terrestrial and aquatic passage

The Design Engineer's challenge is to design the most economical structure which will satisfy all these constraints. More detailed guidance on these topics is provided in Chapters 8 and 9. With respect to allowable backwater and scour velocities, certain field data must be collected to establish these parameters. Obtain elevation data on upstream development in the vicinity to determine if structures are near the observed or known high water elevation. To estimate scouring velocities in a channel, it is necessary to describe the type of material in the stream bed and determine whether scour occurs in the natural channel.

In addition to the above, the field reconnaissance should serve to:

- visually acquaint the design engineer with conditions and constraints of the site, such as obtaining overtopping elevation to determine existing level of service, or assessing potential impacts of grade adjustments
- identify topographic features missed in prior surveys
- verify data obtained from other sources, such as base mapping or other survey data
- identify ponds, lakes, reservoirs, and other stormwater retention areas which may affect discharge rates
- review existing drainage features and obtain information on performance
- review potential outlet facilities and downstream conveyances for performance, adequacy, stability, and condition
- identify sediment-sensitive areas such as lakes, ponds, and channels
- review contributing watershed characteristics (e.g., pasture, wooded, industrial, residential)

- identify new or planned construction or proposed development
- locate and/or verify wetlands and other environmentally sensitive areas (to note any obvious discrepancies which may need review by the Environmental Analysis Unit)
- obtain by survey or verify from structure inspection reports or Location and Surveys data details of size, location, length, material type and condition of existing drainage structures
    - for existing box culverts to be retained or extended:
        - top slab and vertical interior web (wall) thicknesses
        - inlet bevel, if present
    - for existing bridges:
        - pier widths, footers, abutments, mud sills
- assess existing structure's condition
    - if in question (e.g., cracks, perched, spalling), follow up by contacting the Structures Management Unit and/or the Materials and Tests Unit, as applicable, to obtain a structural integrity evaluation
- obtain channel data (see Chapter 11)
- obtain historical flood and other stream flow information such as:
    - maximum and other large flood levels at, upstream, and downstream of the study site
    - dates of these occurrences and frequency
    - more frequent flooding levels (e.g., annual, two-year, five-year)
- note any channel scour and migration
- note drift potential, debris size and quantity
- obtain descriptive photographs of site (e.g., upstream and downstream view from road, face of structure upstream and downstream, evidence of scour, floodplain characteristics, structures in floodplain), noting location and direction of view

5.2.2 Drainage Data Collection

Additional drainage survey data and supplemental topographical information which should be collected include:

- elevations of flooding (high water marks, historical flood levels)
    - drift
        - fences are good collectors of drift
    - erosion, such as:
        - cultivated field scoured down to bare clay or gravel in the low areas
        - eroded stream banks
        - scour hole at the outlet of a drainage structure
        - roadway shoulder eroded below the pavement with all the fines washed out
    - deposition of streaks of sand and gravel in a field or on pavement
    - presence of excessive sediment deposits in a channel
    - high water marks on trees and structures
    - flow patterns in matted grass

  - Obtain local flood history information from the local Division maintenance personnel and residents or service personnel (mail carrier, school bus drivers, etc.) who may be familiar with the project site. Conditions found to indicate potential damage to the road should be addressed in the development of the final design recommendations on how to safely convey storm runoff. Reliable high water mark elevations should be recorded on Bridge and Culvert Survey and Hydraulic Design Reports (BSRs and CSRs).
- elevation of upstream and downstream features which could control the design, such as buildings, roads, yards, fields, and other drainage structures
- stream bed elevations for a sufficient distance upstream and downstream to establish the normal stream gradient
- floodplain and channel cross-sections for backwater analysis and channel realignments
- structure geometry and related data needed for hydraulic model analysis (e.g., rail height, pier widths, guardrail, sediment accumulation)
- development and land cover in floodplain for determination of flow resistance and distribution (e.g., roughness coefficients for hydraulic model analysis)
- general description of stream bed and bank materials (clay, silt, sand, gravel, cobble, rock, etc.)
- depth to rock
  - if extensive rock is visible, explore extent by probing bed on culvert size streams for possible footing depth. If warranted, geotechnical unit should be contacted for more detailed investigation.
- locations of high undercut areas where berm ditches are needed
- locations of top of bank along upstream and downstream channel for sufficient distance to establish riparian buffer limits for assessment of impacts in buffer zones
- locations of springs, seeps, or noticeable high-water tables
- potential locations for Stormwater Control Measures (SCMs), if required
- evaluation of wetlands and jurisdictional streams shown in base mapping on roadway plans to ensure accuracy for permit application
  - coordinate with EAU as soon as possible if any significant discrepancies are encountered

Additionally in urban areas, where curb and gutter roadway typical section is proposed:

- locate and obtain elevations of driveways and low areas behind proposed curb where drainage inlets may be needed
- locate and obtain elevations of offsite drainage system behind proposed curb
- locate small inflow systems such as roof and basement drains

Review and obtain the following information for use in bridge scour analysis:

- description of floodplain
- channel bed material (e.g., sand, silt) and gradation (e.g., fine, medium, coarse)
- evidence of scour at existing structure, particularly at the abutments and interior bents

- channel cross-sections at bridge face and at locations of the upstream and downstream toe of the embankment
- photos to support the selection of roughness coefficient values, hydraulic control features, etc.
- elevation and location of deepest point in channel (thalweg – not necessarily at center of stream)
- type and condition of existing foundation, if visible
- any repairs/bank stabilization, if visible

All pertinent data gathered through this field reconnaissance and survey should be recorded on work plans, field notes, and filed with project documentation. Important project documentation should also be preserved in a digital format, such as a MicroStation CADD file or scanned PDF file. The Drainage Design Field Investigation Checklist should be completed while conducting the field study.

5.2.3 Field Safety

All personnel performing field reconnaissance who work for NCDOT must follow the policies and guidance in NCDOT's Safety Policy and Procedure (SPP) Manual (NCDOT 1995) and Workplace Safety (Operations Procedures – SOP) Manual (NCDOT n.d.).

There is no specific published guidance or policy pertaining exclusively to NCDOT roadside work by field survey crews. Roadway Standard Drawings (NCDOT 2012) Division 11 contains NCDOT standards for work zone traffic control, which may be consulted as a reference for general information and guidance on such things as flagging traffic and placement of roadside warning signs, cones, and other traffic control devices, as may be applicable. It should be noted that NCDOT requires personnel trained and certified by an approved source to perform traffic flagging. If required, coordinate with the local Division office to ensure that appropriate personnel are assigned to serve in this capacity.

If surveys are needed within a railroad right-of-way, arrange a permit of entry by coordinating with the Location and Surveys Unit and the Rail Division. This work may likely be outsourced to qualified and certified contractors approved by the railroad owners. Under no circumstance should a hydraulic survey field crew enter a railroad right-of-way without an authorized permit of entry.

5.3 Drainage Plans

5.3.1 Development Process

Using the preliminary roadway plans as a base, develop the drainage plans in the MicroStation Drainage (DRN) file, and proceed as follows:

1. As necessary, verify and supplement all existing drainage features (structure type, size, elevations).
2. Contact the Location and Surveys Unit for clarification or revision if major discrepancies or errors are discovered in the field, or if significant supplemental surveys are needed beyond typical scope of a hydraulics field review.
3. Note all existing drainage divides, flow directions, ditches, channels, etc. Transfer important notes on hardcopy plans to the digital MicroStation plan drawings on the appropriate information levels, such as notes about existing pipe conditions, erosion problems, etc.
4. Verify and supplement information addressing utilities that may affect drainage features.
5. Sketch any special ditches or other topographical features identified during field surveys and not included on the preliminary plans.
6. Make notes of design controls identified during data collection and field survey stage, such as elevation of lowest adjacent grade (LAG) of buildings in floodplain, which could potentially be adversely affected.
7. Determine and evaluate the patterns of surface flow as affected and developed by the project construction. Note flow direction and areas of flow concentration for clarity, as needed
8. Develop a schematic layout of drainage features (bridges, box culverts, pipes, storm drain systems, ditches, channels, etc.) to properly convey surface flow within and adjacent to the project. Note these features on the plans
9. Perform the design studies required to detail each drainage feature (type, size, location, material, etc.) and document the design detail of each individual feature as directed in the related section of these *Guidelines*.
10. Upon completion of hydraulic design, prepare a final set of redline drainage plans, in electronic PDF and CADD versions. These should include the following items as a minimum (see Section 5.4 for additional items to consider):
    - drainage areas (label size and show boundary depictions)
    - existing drainage patterns (see Section 5.4.1)
    - storm drain system inlets, pipes, etc., with top and invert elevations and structure numbers
    - ditches and outlet channels, with details, plan/profile views and computations, as appropriate
    - topographical contours, including flow areas where needed for clarity
    - important design notes, including information from field investigation, utility conflicts, commitments, retaining or removing items, etc.
    - sag and crest locations on roadway with flow direction arrows
    - stream tops of banks
    - quantities of excavation, rip rap, geotextile fabric, etc.
    - culvert and cross-pipe hydraulic data
    - permanent and temporary drainage easements

- limits of shoulder berm gutter at bridges

11. The Checklist for Drainage Study and Hydraulic Design must also be finished and included with the project documentation upon completion of design.

5.4 Items to Include on Redline Drainage Plans

5.4.1 Field Reconnaissance Items

- Clearly show existing drainage patterns. This is important not only for review, but also as a record of pre-project conditions.
- Show existing contours with readable elevations at a contour interval appropriate for the terrain.
- Mark existing ditches (and labeled if not clear), with a continuous series of arrows for the extent of the ditch.
- Mark general overland flow patterns (non-ditch) with arrows as needed in addition to contours.
    - Pay particular attention to areas where contours are indistinct or difficult to discern, or where contours alone are not adequate (such as areas adjacent to the slope stakes that are not well reflected in the contours). Do not use the same arrow symbology for overland flow as for existing ditches to avoid confusing the two.
- Note existing pipe condition (especially if retaining or plugging), any erosion/problem notes, etc.
- Provide descriptions for all existing ditches (other than roadside ditches that appear in the cross sections) to show existing channel geometry dimensions. Ditch descriptions should include water depth (if applicable) and type of cover/condition for outfall ditches.
- Note the condition of existing ponds/spillways within the project area. Note spillway/outlet locations and any draw down pipe sizes.
- Show top of banks for major drainage structures.

5.4.2 Hydraulic Design Items

- Mark proposed grade sag/crest locations on plan sheets. Indicate direction of grade (with an arrow pointing in the downgrade direction) for any alignment that does not have a sag/crest marked on that sheet.
- Mark tops/inverts marked on the redline set, including cross pipes and equalizer pipes.
- Show all required TDE/PDE on plans for review.
- Label proposed ditches (plan view) and alignment/stationing filled in for ditch

details. Include ditch labels with base width dimension for base ditches.

- Set minimum depth on ditch details to contain the design flow plus freeboard and specify to the whole or half-foot (one foot or greater).
- Show drainage area boundaries for all ditches/inlets/pipes. If drainage area extends off sheet, provide readable contour map at an appropriate scale that shows full delineation of drainage area.
- Show Q10/V10 for all ditches entering (or discharging adjacent to) wetlands, and include all variables used in analysis on redline set.
- Draft buffer zones (BZ1 & BZ2). Be careful about drafting around acute angles. Do not just Copy Parallel.
- Document design notes on redlines as needed, to explain design decisions and document other issues not readily apparent.
- Do not turn off any levels/reference files that are required for R/W plans, such as property owners.
- Show cross pipes and design data block from Pipe Data Sheet on the profiles.
- Include all variables on ditch comps (including Manning's 'n'/side slopes).
- All features requiring grading, including but not limited to special ditches, stormwater BMPs etc., shall have a grading plan including, at minimum, slope stake lines. Inclusion of proposed contours is preferred.
    - Contours are required for stormwater BMPs with a basin component proposed
- Details shall have clear dimensioning including, but not limited to, side slopes, base widths, berm widths, depths, etc.

Items preferred to be on redline set plan sheets, but not required if provided separately:

- ditch computations
- outlet (pre/post) analysis summary
- overpass spread computations

5.5 Completing 3D Series Hydraulic Summary Plan Sheets (Including Drainage Summary Sheets and Stormwater Control Measure Summary Sheets)

Construction plan sheets include 3D Series drainage summary sheets. Traditionally, these sheets have included the summary of pipe and drainage structure types. With the implementation of Project Delivery Network (PDN) version 2.0, the 3D series sheets will now also include stormwater control measure summaries for projects where stormwater

controls are included. Not all projects will include stormwater control measures; these sheets should be the last sheets within the 3D series.

5.5.1 Drainage Summary Sheets

Drainage summary sheets should be completed per guidance in the Drainage Summary Sheet – Steps for Hydraulic Users

Once the traditional drainage summary sheets have been completed, the user should add the stormwater control summary sheets starting with the next available consecutive sheet number.

5.5.2 Stormwater Control Measure Summary Sheets

The Highway Stormwater Program (HSP) has amended the Stormwater Management Plan (SMP) template to automate the creation of the Stormwater Control Measure Summary Sheet. Hydraulic Design Engineers are required to complete an SMP for all projects and should always use the latest SMP template version.

Users should complete the SMP per the instructions included in that document. Users should complete the "general project information" and "waterbody information" tabs along with any applicable stormwater control measure tabs (swales, filter strip, PSHs and energy dissipators, level spreader and HSB, other toolbox BMPs, other non-toolbox BMPs). These tabs are illustrated in Figure 1.

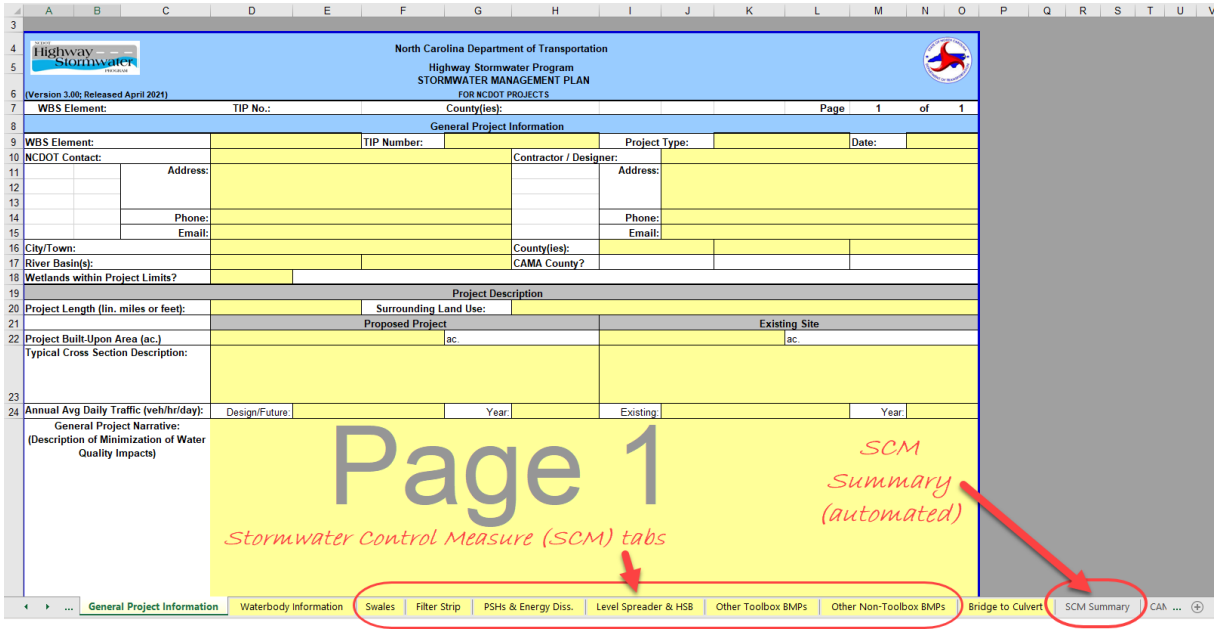

Figure 1. Stormwater Management Plan Template

As a user completes the SCM tabs on the SMP:

1. the SCM summary tab will be auto-populated and sorted by plan sheet number, alignment (L, Y1, etc.), and station
2. after completion of the SCM tabs, click on the SCM summary tab
    a. table should be complete and sorted
3. complete the computed by and checked by with dates box in the upper left corner of the first sheet, cells D7, D8, F7, and F8 (see Figure 2)
4. complete the next consecutive 3D series plan sheet number in the upper right corner of the first sheet, cell Z8

Any additional sheets will be automatically numbered. All other cells within the worksheet should be locked and non-editable. The worksheet print area is preset to include only the first sheet. If additional sheets are needed, expand the print area manually to include those sheets. Once the print area is set appropriately, print the sheets to PDFs at the ANSI D size (22”x34”, full-size plan sheet).

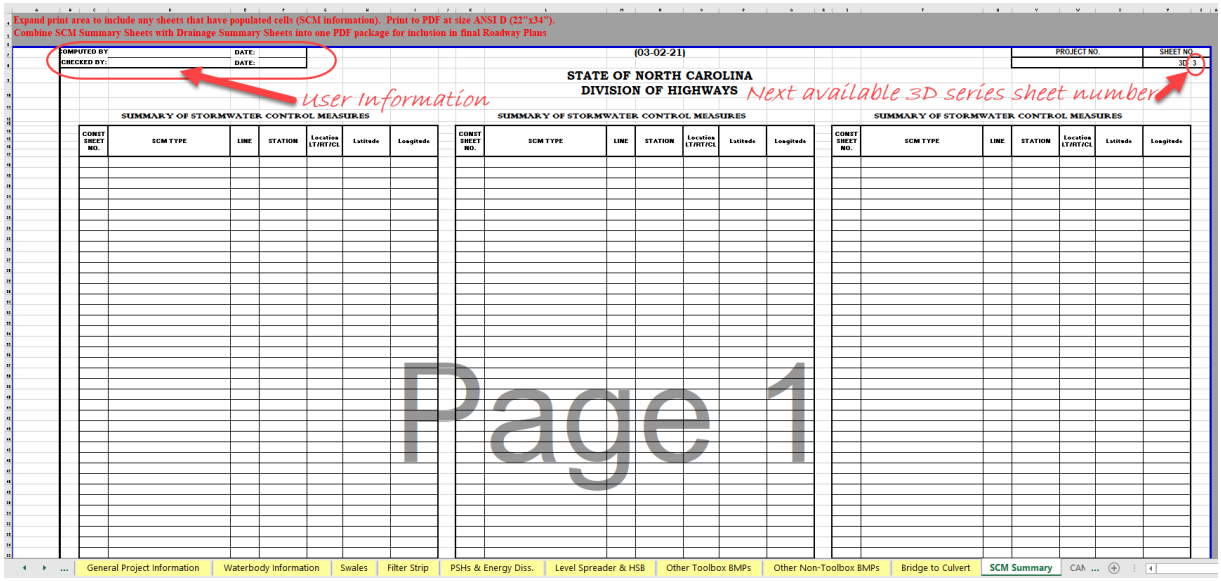

Figure 2. Stormwater Control Measure Summary Sheet

5.5.3 Deliverables

The printed PDF should be combined with the drainage summary sheets to create one consolidated PDF file. The total 3D series sheets PDF file should then be sent to the project Roadway Design Engineer to be incorporated into the final plan set. The final SMP should be uploaded to the Preconstruction Connect site via the ATLAS workbench.

5.6 Sealing of Drainage Plans and Design Reports by Professional Engineer

The final plans are signed and sealed by the responsible North Carolina Professional Engineers who performed or supervised the engineering work. Procedures for electronically sealed plans have been implemented within NCDOT. Typically, the hydraulic design engineer will need to seal the title sheet, any special detail sheets with drainage-related details, and all plan and profile sheets. If Bridge or Culvert Survey and Hydraulic Design Reports (BSRs or CSRs) are included with the project, the hydraulic design engineer must also certify that the information in these reports and the plans is accurate, as they also are to be signed and sealed by a licensed North Carolina Professional Engineer as part of the official legal design documentation for the project. Additionally, as noted in Chapter 1 Introduction, documentation corresponding to the project's Project Delivery Network (PDN) package must be individually sealed by the responsible engineer.

5.7 References

NCDOT. (1995, December). *Safety Policy and Procedure Manual.* Retrieved November 2021, from Safety & Risk Management SPPs: https://connect.ncdot.gov/business/safety/Pages/SPP.aspx

NCDOT. (2007 (rev. 2010)). *Field Surveys for Hydrographic Data, Version 2.2.* Retrieved from Location & Surveys Unit, North Carolina Department of Transportation: https://connect.ncdot.gov/resources/Location/Manual%20Documents/Location%20Hydro%20Manual%202010.pdf

NCDOT. (2012). *Roadway Standard Drawings*. (North Carolina Department of Transportation - Roadway Unit) Retrieved November 2021, from https://connect.ncdot.gov/resources/Specifications/Pages/2012-Roadway-Drawings.aspx

NCDOT. (n.d.). *Safe Operating Procedures and Workplace Safety Manual.* Retrieved November 2021, from Safety & Risk Management SOPs.

5.8 Additional Documentation

Hydraulic Planning Report (HPR)

Drainage Design Field Investigation Checklist

Bridge Survey and Hydraulic Design Report (BSR) Key

Culvert Survey and Hydraulic Design Report (CSR) Key

Drainage Summary Sheet for Hydraulics Users Guide

Stormwater Control Measure Summary Sheets